

A Framework for Conducting Effectiveness Evaluations of Watershed Restoration Projects

by

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Watershed Restoration Technical Circular No. 12
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EXECUTIVE SUMMARY

1. The purpose of a 'framework for conducting effectiveness evaluations' is to assist people in developing watershed restoration evaluation plans for roads, gullies, landslides, riparian areas and streams. Well designed and properly implemented evaluations are a prerequisite to determining the success or failure of watershed restoration.
2. Effectiveness evaluations of Watershed Restoration Program (WRP) activities addresses three fundamental questions: Is the restoration work achieving the objectives for the targeted resource values; How can watershed restoration techniques be improved to optimize recovery of environmental values; and What modifications are needed to improve the cost-effectiveness of work.
3. Effectiveness evaluations can range from a relatively low intensity level or *routine* evaluations to *intensive* evaluations and to *operational techniques refinement*. Routine evaluations range from a visual evaluation using qualitative variables conducted on all structures and treatments, to a largely quantitative assessment that is conducted on the ground at high priority sites within a project. The purpose of routine evaluations is to look for any obvious failures at all study sites within a watershed using very basic field procedures. Intensive evaluations are appropriate for select projects or select subsets of sites that will provide an opportunity to quantitatively examine rehabilitation treatments in more detail than is possible with routine evaluations. Intensive evaluations rely primarily on direct measures of biological and physical parameters, rather than response indicators. Operational techniques refinement addresses which techniques are working or not working; what are the limitations of treatments with respect to terrain, climate, discharge, gradient, etc., and what techniques work the best under specific conditions.
4. Benefits of effectiveness evaluations to WRP include: more efficient allocation of funding and optimization of planning/decision-making; a measure of the state of recovery of the watershed; and technical feedback to refine restoration treatment designs.
5. The process for inspecting compliance and evaluating effectiveness is part of an adaptive management (including information feedback) cycle: plan, act, inspect, evaluate, and make decisions. Regular feedback of both inspections and effectiveness evaluations resulting from well-defined feedback loops is an essential component of effectiveness evaluations. Analyzing and interpreting evaluation data provides the information to improve WRP management, adjust restoration objectives and refine restoration treatments.

6. A strategy is proposed for the implementation of effectiveness evaluations in the WRP that describes a method for ranking funding priorities and different levels of evaluation intensity. Highest priority for funding should go to completed projects, which are currently being evaluated for effectiveness (Category 1), especially those with long-term design and pre-treatment data. Second priority should be routine evaluations of completed projects on which effectiveness evaluations have not been conducted, but the projects were innovative or done on high risk sites and in high priority watersheds. For routine evaluation of current projects in which major works have not yet been completed, funding should be incorporated into the assessment and implementation stage costs and included in annual project funding. Proposals for intensive evaluation studies on Category 3 projects should be encouraged as an appropriate study design which includes pre-restoration data can be implemented.
7. The most important step in developing inspections and effectiveness evaluation plans is to clearly define the objectives. Watershed, component, and site-level restoration objectives are developed in an hierarchical sequence and provide the basis for all restoration work conducted within a watershed. These objectives must be measurable and quantifiable, and must imply some desired future condition. They may represent standards or guidelines from broad planning or policy documents or they may represent benchmark conditions from healthy watersheds.
8. A plan is proposed to ensure long term maintenance, accessibility and dissemination of data. The development of protocols and training of technical staff are key aspects of sound data collection and the adaptive management cycle. Information feedback is the most important benefit of both inspections and effectiveness evaluations.
9. An overall budget is recommended to implement the proposed strategy for WRP effectiveness evaluations of approximately 6% of the annual WRP budget. A possible funding scenario is suggested for various effectiveness evaluation levels. This scenario would provide funds for routine, intensive and operational techniques refinement evaluation projects.



1.0 INTRODUCTION

1.1 Purpose and Scope of Document

Forest Renewal BC's (FRBC) Watershed Restoration Program (WRP) has been in operation since 1994, carrying out rehabilitative works to enhance environmental values in watersheds impacted by past forest practices. This document is intended as a strategic framework for the development of a province-wide program for effectiveness evaluations of restoration treatments implemented under the WRP. The fundamental questions addressed by effectiveness evaluations of WRP activities are:

1. Is the restoration work achieving the objectives for the targeted resource values;
2. How can watershed restoration techniques be improved to optimize recovery of environmental values; and
3. What modifications are needed to improve the cost-effectiveness of work.

The document will be relevant to anyone who may be involved in the administration and/or development of WRP effectiveness evaluation programs. Section 3.0 briefly addresses some of the technical aspects of evaluation design. Section 4.0 presents recommended strategies for project selection, funding levels, evaluation, data management and training. The document provides a rationale for effectiveness evaluations of restoration works and describes the key components that should be considered in any design.

1.2 Description of FRBC's Watershed Restoration Program

The FRBC-funded Watershed Restoration Program is one of the larger coordinated programs of its type in the world that addresses the rehabilitation of watersheds degraded by past forest practices. It began as a provincial initiative under the Forest Renewal Plan funded through Forest Renewal BC, a crown corporation founded in April, 1994. The goals (2000-2005) of WRP are to:

1. restore and protect fish habitat and water quality in high priority watersheds adversely affected by forest harvesting practices that, without intervention, would require decades to recover naturally;
2. provide better knowledge, information and tools to strengthen sustainable management of watersheds; and
3. provide community-based employment, training and stewardship opportunities.

Since the program began, restoration prescriptions and treatments have included techniques that are both proven and innovative. Given that the program is anticipated to have another 20 to 30 years of operation, it is imperative that evaluation of the suitability and effectiveness of these techniques be conducted, especially given the scale of the WRP and potential for improvement in cost-effectiveness (Figure 1).



Figure 1. The Adaptive Management Process for the FERC's Watershed Restoration Program

Other programs that are central to the operations of government agencies are complementary to, and link with, WRP. An example is the Ministry of Forests Quality Assurance Program (Ministry of Forests 1999).

1.3 Purpose and Benefits of Inspections to WRP

Inspections are conducted during the course of watershed restoration activities to ensure that the work is completed as prescribed or to the standards defined in the contract. The main purpose is to ensure that errors and omissions are corrected prior to payment. Inspections are typically required for all projects with field inspections carried out both during and at the completion of restoration works.

1.4 Purpose and Benefits of Effectiveness Evaluations to WRP

While the focus of effectiveness evaluations for watershed restoration will be to optimize both the management of the Watershed Restoration Program and specific restoration techniques, information may also influence or change broader management policies for watersheds. For example, information from effectiveness evaluations can influence forest development plans, Forest Practice Code regulations, fisheries, water and other resource management policies. Evaluation results will also help to refine the functional relationships such as biostandards, which are applied to some program outputs to estimate potential fish production and to identify research opportunities to develop such relationships.

Effectiveness evaluations help in determining the degree to which rehabilitation activities attain the restoration objectives set out in the planning phase. Under WRP, effectiveness evaluations are envisioned to comprise a provincially coordinated component to evaluate project effectiveness and provide an adaptive feedback loop for future restoration works. It is generally accepted that a well-designed effectiveness evaluation program has the potential to pay for itself many times over through increased cost-effectiveness, thus providing a significant return on investment.

Benefits of effectiveness evaluations include:

- more efficient allocation of funding and optimization in planning/decision-making (program benefits);
- a measure of the state of recovery of the watershed (i.e., how much restoration has been achieved, how much more effort is required); and
- technical feedback to refine restoration treatment designs.

Additional benefits include: a technical basis to demonstrate fiscal accountability and the effectiveness of public expenditures; refinements to best management practices, as well as the Provincial Forest Practices Code; identification of areas/issues where research studies may be required; and opportunities for training and increased stewardship through participation of local community members in evaluation programs.

1.5 Status of Current Effectiveness Evaluations

To date, it is mainly inspections that have been carried out in the Watershed Restoration Program. In the few cases where effectiveness evaluations have been carried out, sampling protocols have not been standardized across regions or the province. For hill slopes, effectiveness evaluations have usually consisted of visual inspections of treatments across a wide range of conditions.

For the instream component, effectiveness evaluations have focused on more detailed evaluations and assessments of a few sites. Although individual project reports have been prepared, the results of current effectiveness evaluations are generally not being effectively incorporated into future project or program plans. This situation is slowing the rate of improvement in WRP techniques and effectiveness. A situation analysis is needed to determine what types of evaluations are already in progress, or have been completed, and how successful they have been.

2.0 TYPES OF EVALUATIONS

Two main types of evaluation with indirect linkages are common in watershed restoration projects (Figure 2):

- Effectiveness Evaluations: How well are the restoration objectives being met?
- Validation Evaluations: Are the key assumptions valid?

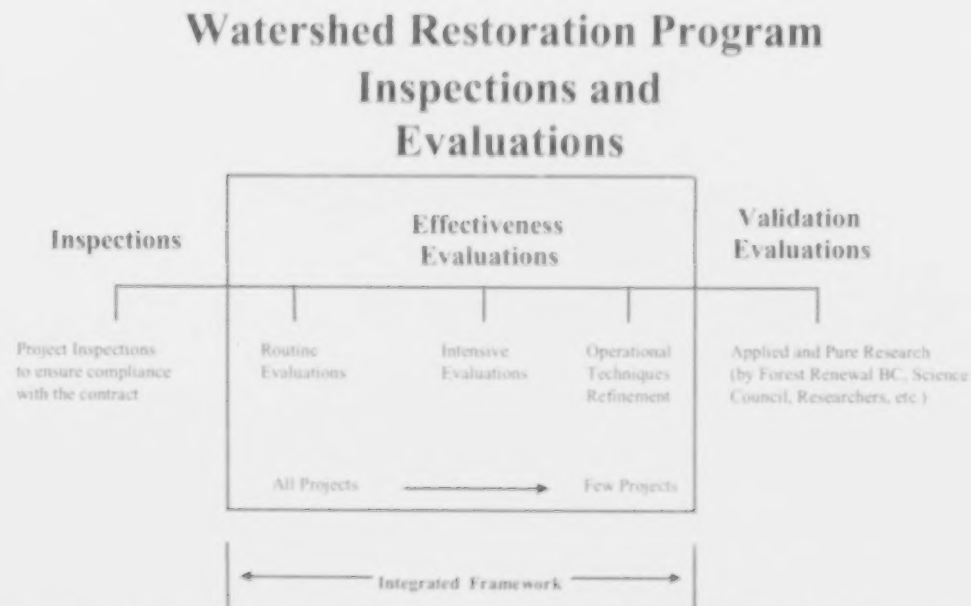


Figure 2. Inspections and evaluations associated with the BC Watershed Restoration Program.

2.1 Effectiveness Evaluations

Measurements of system responses can be performed at varying levels of intensity and there are benefits and limitations associated with each level. Measurements may be dependent upon the effects of specific activities or the combined effect(s) of a number of activities. For any type of effectiveness evaluation, a key consideration is the collection of easily measured field-based data using repeatable methods.

Three levels of effectiveness evaluation are presented (Figure 2):

- A relatively low intensity level or *routine evaluation* calling for typically inexpensive and rapid routine data collection.
- An *intensive evaluation* level involving specialized study design with much more expensive and time-consuming data collection and analysis.
- A third level of effectiveness evaluation, termed *operational techniques refinement*, is generally focused on machinery, techniques or cost efficiency.

Table 1 shows the general distinctions between routine evaluation, intensive evaluation, and operational techniques refinement.

2.1.1 Routine Evaluations

Routine evaluations are the low cost overview evaluations preferred on the majority of restoration sites. It is typically a low intensity, mainly qualitative activity to determine the functionality, condition and longevity of the restoration works. This is a less rigorous form of effectiveness evaluations that often involves visual estimates or photographs to demonstrate changing resource conditions over time.

The main objectives of routine evaluations are to:

- assess the present configuration and condition of restoration treatments (i.e., are the works still in place);
- through the assessment of a number of key variables, qualitatively assess whether or not the treatments have been effective in addressing the restoration objectives (i.e., are the works functioning as intended);
- determine if remedial work is needed; and
- identify specific areas (hill slope portions, road networks or individual roads/landslides, etc.) which may warrant a more rigorous evaluation or a more specific investigation (i.e., an effectiveness audit).

Table 1. Description of Effectiveness Evaluation Levels^a

¹¹ <http://www.legislativo.rio.de.br/legisweb/legisweb.asp?menu=legisweb>

Intensive Evaluations

Intensive evaluations are more detailed than routine evaluations. Intensive evaluations are specialized studies of functional relationships that are fundamental to measure restoration success. Intensive evaluations are appropriate for select projects or select subsets of sites that will provide an opportunity to quantitatively examine rehabilitation treatments in more detail than is possible with routine evaluations. Typical questions answered include: which techniques are working or not working; what are the limitations of treatments with respect to terrain, climate, discharge, gradient, etc; and what techniques work the best under specific conditions.

Some objectives of intensive evaluations include:

- determine state of recovery in a treated watershed;
- investigation of the interaction(s) between multiple component activities;
- determination of the effectiveness of individual and multiple component activities (restoration treatments) in achieving the various component objectives; and
- determination of long term treatment effectiveness.

The more focused and refined objectives of intensive evaluations generally require data collection in greater detail and, typically, in higher frequency and of longer duration. However, techniques, frequency and duration can not be determined until the exact objectives of the study are known and the evaluation variables have been identified.

2.1.3 Operational Techniques Refinement

Operational techniques refinement is a special category of effectiveness evaluations that requires control and manipulation of restoration treatments in order to answer the questions: did a new treatment work, how well did it work relative to other treatments, and at what cost did it work.

The principal objectives are:

- to test a new technique, application, or technology in order to quantify effectiveness in achieving restoration objectives, typically at the component level (the term "technical efficiency" can be defined as the effectiveness of a machine or process in accomplishing a restoration objective); and
- to determine the cost-effectiveness of the new technique, application or technology.

Operational techniques refinement applies to a small number of projects in which there is a need to test and select the best treatment for meeting restoration objectives. Test methods may require specialized experimental design, but they may also require consultation with manufacturers/producers to establish test protocols if they have not already been established. Operational techniques refinement may be undertaken as a one-time test, but this is largely dependent on the defined evaluation objectives.

Documentation of results of operational techniques refinement is critical if the cost-effectiveness of restoration treatments is to be realized.

2.2 Validation Evaluations

Validation evaluations are more specialized and primarily a research tool with which to examine the basic scientific understanding of how ecosystems work. It refers to testing of hypotheses that pertain to our level of understanding of how or why a system responds to a disturbance or treatment. The purpose of validation evaluations is to verify the basic assumptions upon which the restoration works are based. For example, up to 20 years ago, large woody debris was considered only an impediment to fish movement and was removed from streams (Sedell et al. 1988). Research has now shown that woody debris is important in structuring stream communities, providing a link between the physical and biological functions in streams (Maser and Sedell 1994).

3.0 DEVELOPING AN EFFECTIVENESS EVALUATION PROGRAM

3.1 Adaptive Management

Adaptive management is a formal process that can be used to continually improve (resource) management policies and practices by learning from the outcomes of operational programs. It requires documentation of objectives, assumptions, decisions, and outcomes, and includes:

- designing management policies and evaluation schemes in a way that provides reliable feedback;
- evaluating responses of key indicators, over appropriate time frames and spatial scales; and
- analyzing and evaluating data, and using the information to improve management, adjust objectives, and refine restoration treatments (Taylor et al. 1997).

Its most effective form, *active adaptive management*, is characterized by management programs that are designed to experimentally compare selected policies or practices by testing alternative hypotheses about the system being managed. Adaptive management has been described by Taylor et al. (1997) as:

"a systematic approach to improving management and accommodating change by learning the outcomes of management interventions. Not only are objectives and policies adjusted in response to new information, but management policies are deliberately designed to enhance the rate of improvement by: providing reliable feedback about which policies, plans or practices are effective and which are not; and increasing understanding about ecosystem function and identifying thresholds in ecosystem response".

When several different treatment techniques are applied on a large spatial scale, such as in WRP, uncertainty regarding overall effects is inevitable. Adoption of an adaptive management (including information feedback) approach serves to minimize risk. Effectiveness evaluations must be consistent with such an approach to encourage learning and provide feedback to the entire range of watershed restoration activities.

Developing either a monitoring program or an effectiveness evaluation program for WRP involves consideration and decisions on the fundamental steps of the program framework before starting (Figure 3). A determination of effectiveness evaluation objectives and budgetary and logistical constraints will be determined for each project, and will dictate the most appropriate level of evaluation. In most cases, balancing the cost against the level of detail will be a critical step and may require a screening process to determine which areas warrant additional expenditures to capture more detail. Evaluation variables should be selected that fit the levels of effectiveness evaluations, and the specific effectiveness evaluation questions. Results from the evaluation, particularly during the first year (i.e., pilot), will feedback to refine evaluation questions, sampling design, and variable selection. Results will provide the information to improve restoration treatments, including treatment design and application. Also, results from the effectiveness evaluation program will provide feedback to WRP planning and implementation to re-focus WRP goals and objectives and the allocation of expenditures on effective restoration treatments (Figure 1).

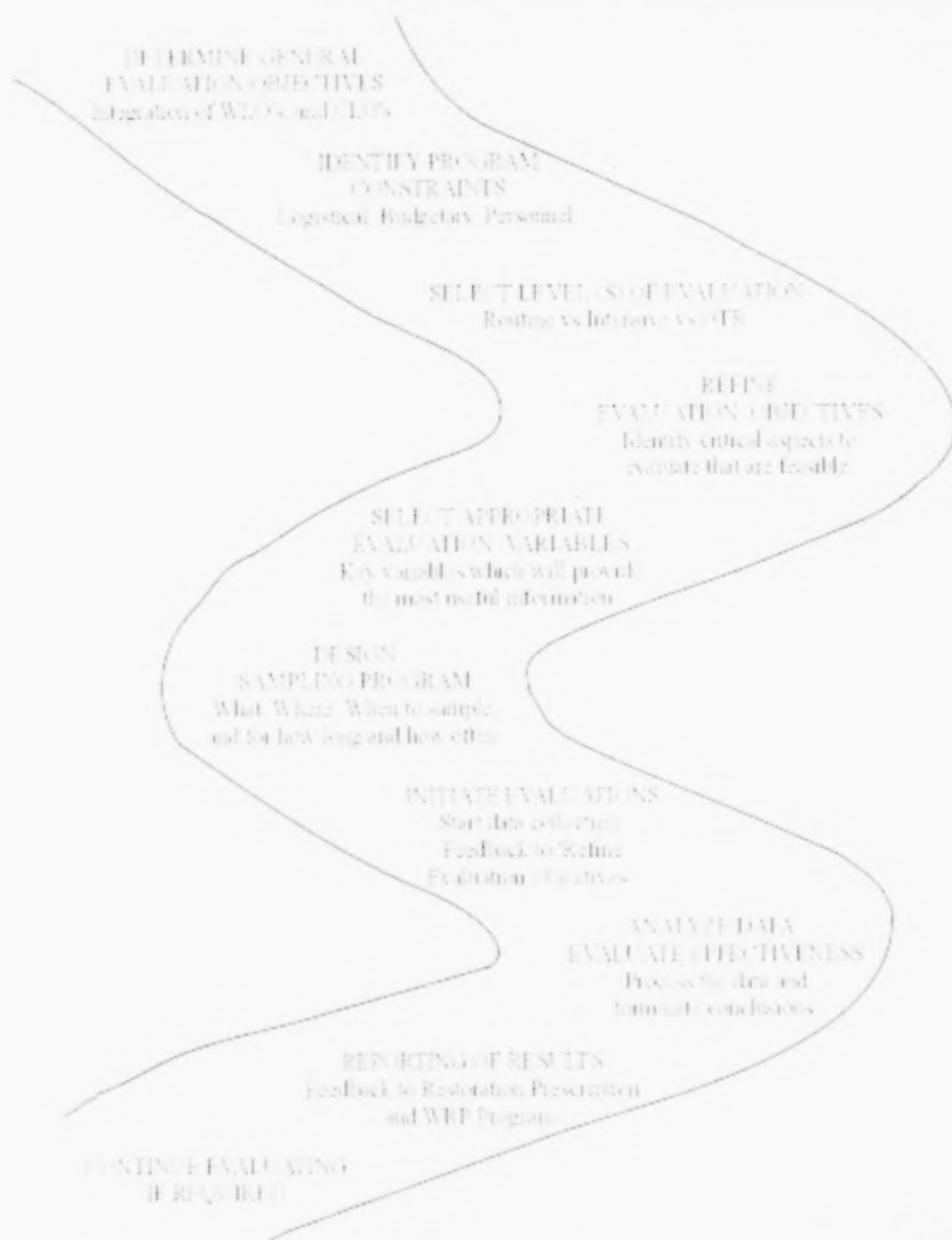


Figure 3. Phases in the development of an effectiveness evaluation project (modified after MacDonald et al. 1991).

3.2 Establishing Restoration and Evaluation Objectives

Watershed, component, and site-level objectives provide the basis for all restoration work conducted within a watershed. These objectives must be measurable and obtainable and imply some desired future condition. They may represent standards or guidelines from broad planning or policy documents or they may represent benchmark conditions from healthy watersheds (Kershner 1997).

It is important to understand the linkages between *restoration objectives*, *restoration activities* and *effectiveness evaluation objectives*. Restoration objectives are developed initially at a broad watershed level and are further focused at the component and site levels. Component level objectives (CLOs) include the road, gully, landslide, riparian and stream components within a watershed. Site-level objectives (SLOs) include distinct site features within each component; for instance, cutslope, fillslope, running surface, and ditches are sites that make up the road component. Where possible, restoration objectives should be phrased to address a particular watershed process, whether physical or biological.

The advantages of this hierarchical or 'nested' sequence of objectives include:

- ensuring that all the work undertaken is consistent with and directed towards the highest priority objectives of the watershed;
- clarifying the linkages among different component activities; thus, facilitating the coordination and scheduling of component projects; and
- providing definite measures of performance that can be used to track the progress of the projects (Johnston and Moore 1995).

Another advantage of the hierarchical sequence of objectives is that it not only facilitates the effectiveness of treatments at the site level, but also evaluates effectiveness at the component level by grouping results of site-level investigations. Similarly, grouping at the component levels provides a means to determine whether watershed scale objectives are being met.

Restoration activities comprise all physical works intended to achieve the restoration objectives. For the hill slope components of restoration, physical works may include activities such as deactivation of roads, revegetation of landslide scars, or removal of unstable material in gullies. Corresponding activities for riparian and stream components include silvicultural management, such as planting, spacing, and brushing for riparian sites, and stream works such as woody debris placement and creation of back channels needed for rearing of juvenile fish.

As illustrated in Figure 4, effectiveness evaluation questions show the relationship of the prescription to what achievement was intended by the objective. With these linkages, questions may address one or more objective levels. The question, 'Have LWD structures

increased residual pool depth?' directly tests the effectiveness of the prescription, 'Install LWD structures in pools at chainages 500, 550, 600 and 655 m', at achieving not only the SLO, but also the component level objectives. The question, 'Has the cover on pools used by coho and rainbow trout increased?' directly tests the CLO, 'Increase habitat cover for juvenile coho and rainbow trout'.

To ensure clear goals for effectiveness evaluations, and to preclude unrealistic expectations, the objectives must be clearly identified and defined at the start of program development. Simply stated, objectives demonstrate the reason(s) for conducting effectiveness evaluations. For example, routine evaluations may be conducted "to identify areas requiring remedial work". Once assembled, evaluation objectives may be fine-tuned after a decision on the level of evaluation has been made and critical aspects of the treatment that require evaluation have been prioritized.

Objectives may also address particular aspects of restoration activities; for instance, comparing results from various types of landslide revegetation applications (e.g., hydroseeding vs dryseeding). Specific studies such as this may be addressed through more rigorous evaluations, such as operational techniques refinement.

3.3 Integration of Evaluation Efforts

An integrated approach to evaluation is envisioned for all WRP projects. This direction includes setting objectives, implementing assessments, restoration and evaluation. The establishment of restoration objectives and prioritization of restoration sites requires an integrated approach due to the interconnections between physical and biological processes (Figure 5). Setting restoration objectives and prioritization of sites for restoration will consider:

- an evaluation of the magnitude of the present or potential impact of the particular site on fish habitat and/or aquatic resources; and
- an evaluation of the importance of the proposed restoration works at providing improvements to fish habitat or aquatic resources in a short or long term, with due consideration that the works will not be adversely impacted by watershed processes.

An interdisciplinary team of qualified specialists should develop study questions, based on the restoration objectives, and work with program managers and project proponents to design an effectiveness evaluation program that achieves the specified evaluation objectives. Communication and co-ordination between all government ministries and project proponents, who collectively are responsible for the successful delivery of WRP, are pre-requisites to an integrated evaluation program. Thorough integration then ensures the cost-effectiveness of field sampling and data collection is optimized, and that evaluation information is efficiently reported and disseminated.

Watershed Level Objectives

- ◊ Reduce sediment delivery from hillslopes to streams
- ◊ Improve in-stream resting habitat for salmonids

Component Level Objectives

Streams

1. Increase residual pool depth of primary pools
2. Increase habitat cover for juvenile coho and rainbow trout

Riparian Areas

1. Increase potential for stream bank stability
2. Preferentially accelerate conifer growth in riparian reserve zone

Hill Slopes

1. Reduce soil forces that potentially cause angles of internal friction to be exceeded
2. Increase the factor of safety on landslide tracks
3. Reduce the potential for debris flows in gullies

Site Level Objectives

Streams

1. Increase silt in existing pools

Riparian Areas

1. Increase soil cohesion on stream banks
2. Reduce growth competition to conifers from deciduous species

Hill Slopes

2. Increase soil shear strength
3. Decrease amount of unstable material in gullies

Activities (Prescriptions)

Streams

- 1, 2. Install LWD structures in pools at channels 500, 550, 600 and 655 m

Riparian Areas

1. Plant conifers on right bank between channels 5 and 55 m
2. Grow alders on left bank between channels 0 and 200 m

Hill Slopes

1. Permanently deactivate unstable roads between 5 and 8 km along spur 35 (04)
2. Seed and plant trees on landslides identified as A1, A4 and A7
3. Clean gullies of fill at road crossings

Evaluation Questions or Measures of Success

Streams

1. Have LWD structures increased residual pool depth?
2. Has the cover on pools used by coho and rainbow trout increased?

Riparian Areas

1. Is the zone of influence by conifer roots maintaining streambank soil intact?
2. Has banking of alder permitted conifer growth to outpace competitive broad species?

Hill Slopes

1. Has road deactivation decreased the number and size of road-related failures?
2. What area of rehabilitated landslide has continued erosion on exposed mineral soils?
3. Has the size and frequency of debris flows decreased?

Figure 4. Example of the connectivity and sequence from watershed objectives to evaluation questions.

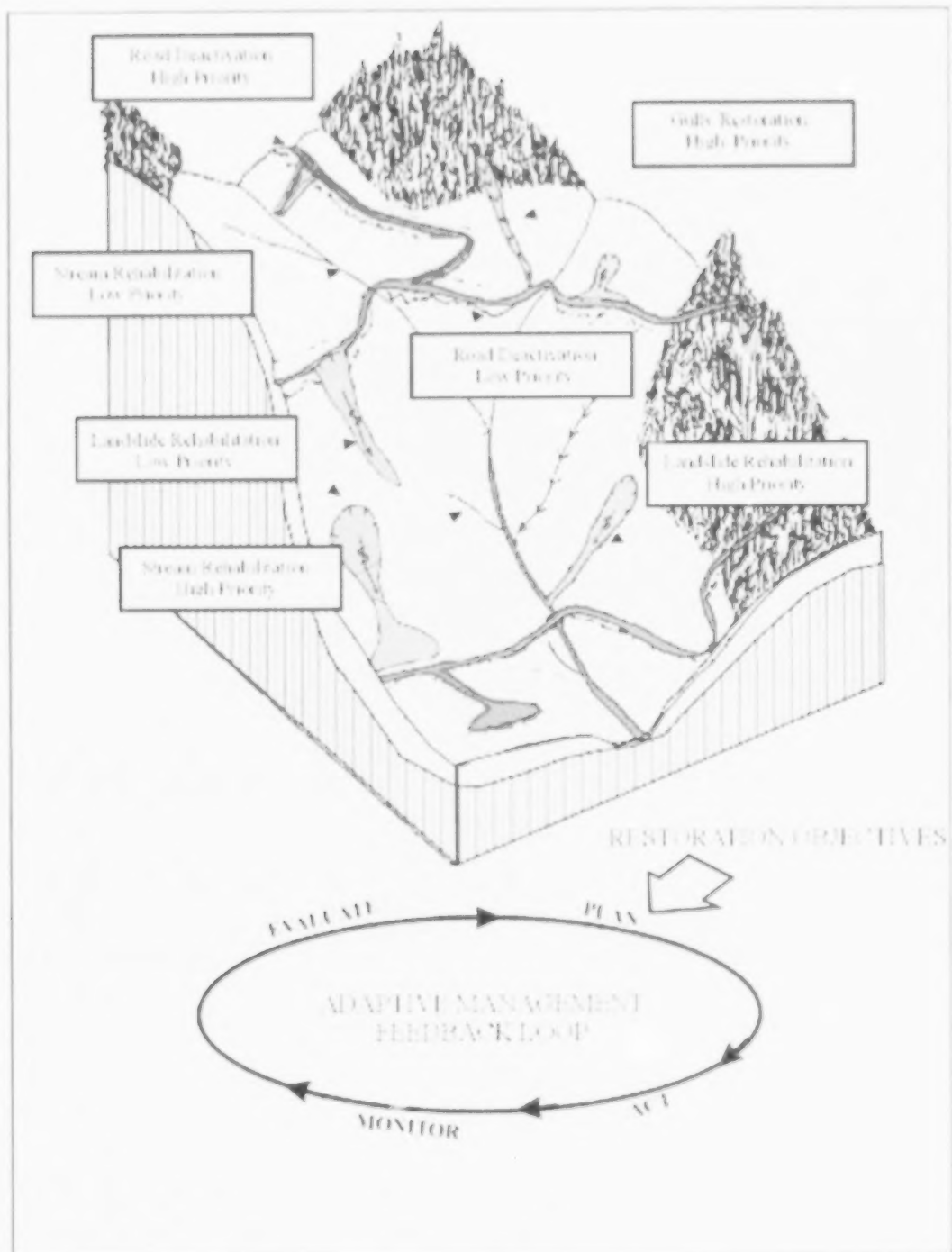


Figure 5. An integrated watershed restoration project, setting restoration objectives and prioritizing stream and hill slope restoration sites in the planning phase.

3.4 Levels of Evaluation

3.4.1 Routine Evaluations

3.4.1.1 Study Design

Routine evaluation ranges from a visual evaluation using qualitative variables conducted on all structures and treatments, to a largely quantitative assessment that is conducted on the ground at high priority sites within a project. Qualitative assessments use indices of response rather than more expensive and time-consuming direct measures. For example, erosion of the road surface is indicated by surface rutting rather than by detailed measurements of sediment generation. Qualitative evaluations can be supplemented with quantitative assessments where low intensity evaluations have identified new, unexpected, unique, or innovative treatment responses, or substandard treatment responses that require further investigation. Routine evaluations are conducted by qualified technicians with specialists providing minimal guidance in study design and sampling protocol. All qualitative and quantitative variables should have a standardized sampling protocol to ensure consistency between evaluators.

For stream and riparian assessments, routine evaluations should involve evaluations on the ground. The lower intensity evaluations should be primarily qualitative using variables with a standardized rating system. More detailed evaluations should include qualitative variables of the lower intensity evaluations, as well as measurements of a limited number of key variables. For hill slope components, routine evaluations at their lowest intensity should involve a visual qualitative assessment of restoration treatments from either an aircraft or low level aerial photographs. Similar to the stream channel and riparian components, more detailed evaluations on the hill slope should also involve measurements of key variables on the ground.

In routine evaluations, qualitative and quantitative assessments of the structure or treatment can be rated using an ordinal (good, fair, poor) or numerical scale rating system. Rating levels are described prior to the field assessment to ensure consistency in the grading of observations and measurements by the evaluator. For example, a four tiered rating system for structural stability of cross ditches or riffles was described by Koning et al. (1998):

- 4 – No movement or rotation of individual elements or structure.
- 3 – Small movement or rotation of individual elements or structure that do not affect performance or cause distress to the structure; no remedial measures required.
- 2 – Large movement or rotation of individual elements or structure that affect performance or cause distress to the structure; remedial measures required.
- 1 – Complete failure; most of the material or structure has moved and it is not functioning as originally designed.

As another example, percent vegetation cover representing biomass, can be measured using categories that were derived from Muller-Dombois and Ellenberg (1974). Three types of vegetation cover were measured: total vegetation, conifer, and willow cover (Northwest Hydraulic Consultants 1999). Categories were as follows:

Category	Percent Cover	Interpretation
1	<1	Pework Condition or Failure
2	1 - 5	Pework Condition or Failure
3	6 - 20	Pework Condition or Closer Inspection Required
4	21 - 50	Established, More Work Required
5	51 - 80	Established
6	>80	Successful

Rating categories for measured values should be based on comparisons with published biostandards (e.g., Slaney and Zaldokas 1997), WRP standards (e.g., Johnston and Slaney 1996), typical road deactivation drawings (Ministry of Forests 1997), FPC guidelines or field procedures (e.g., Forest Road Regulations, Gully Assessment Procedures; Landslide Rehabilitation Assessment Procedures) or other acceptable policy or guideline. Rating categories infer levels of effectiveness based on observations or measurements. For example, in a rating system based on percent vegetative cover, establishment of dense vegetation on a landslide infers a decrease in erosion and sediment delivery.

A standardized rating system allows for:

- a reduction in the subjectivity and bias inherent in assessments conducted by different evaluation personnel;
- a standardized valuation of observations and measurements into well-defined categories;
- simplified compilation and summaries of effectiveness values for all treatments implemented in the watershed, with the opportunity of summarizing up to the program level; and
- an objective basis on which to compare with previous and future qualitative/quantitative evaluations.

Effectiveness evaluations must detect change, so the best variables to evaluate should show direct connectivity or link with the desired component level objective. Routine evaluations at the lowest intensity level will involve a pre-determined set of qualitative variables or questions that are visually evaluated for each sampling occurrence. For more

detailed evaluations, appropriate quantitative and qualitative variables should be selected from a list of variables with standardized sampling protocols. An example of the framework for a routine evaluation project is provided in Appendix 1.

3.4.1.2 Analysis and Presentation of Data

Data analyses for routine evaluations will provide:

- simple graphical displays of effectiveness rating frequencies by structure or treatment type from visual or ground based measurements (Figure 6);
- comparative analyses of how data in treatment areas differs over time;
- tabular inventories of effectiveness ratings for treatments or structures; and
- comparative analysis of key variable data, before and after treatment.

3.4.1.3 Outputs of Routine Evaluations

Reports may include recommendations for improving the methods used, highlighting particular problem areas that should be inspected on a regular basis, and making recommendations for remedial work to repair any damage noted (Ministry of Forests 1996).

More specifically, the outputs from routine evaluations will include:

- summaries of number, type and location of restoration treatments, compiled for each effectiveness level;
- summaries of structural condition and stability of the restoration treatments;
- summaries of treatments that need remedial measures;
- screening to identify structures/treatments that require more detailed routine or intensive evaluations;
- determination of residual risk; and
- a determination on when the next inspection should be done.

3.4.2 Intensive Evaluations

3.4.2.1 Study Design

Intensive evaluations require a well-conceived experimental design. Consultation with a statistician is recommended so that a valid comparison of performance can be obtained through statistical analysis. Statistics provides the scientific basis and procedures for studying numerical data and making inferences about a population (i.e., a larger set of measurements) based on a sample of that population (MacDonald et al. 1991). It also provides an objective means to optimize the location, times of sampling and number of samples; thereby, reducing evaluation costs (MacDonald et al. 1991).

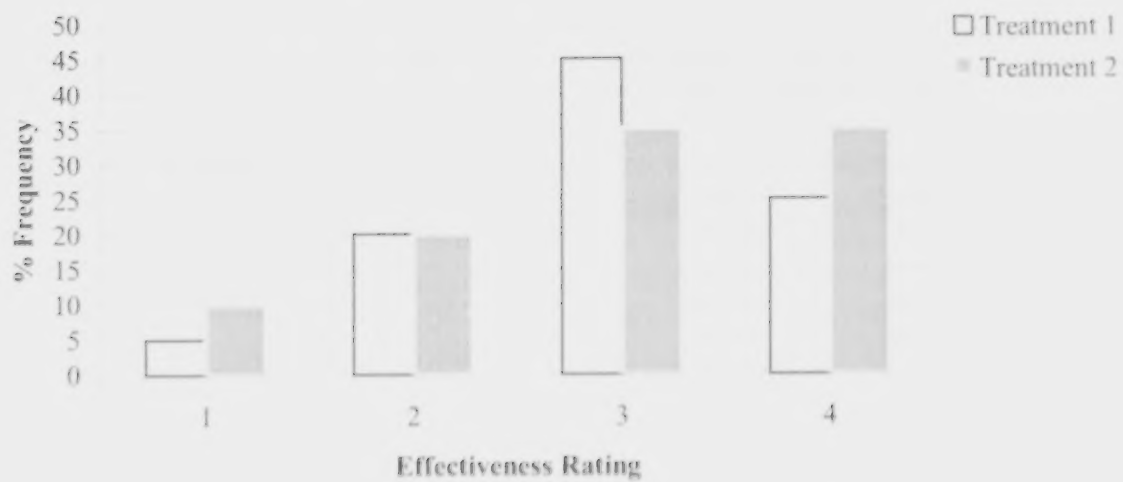


Figure 6. A typical comparison of the effectiveness ratings for two restoration treatments.

A number of approaches to intensive evaluations are envisioned and detail will vary with the character of the watershed. One approach for study design is to compare the effects of restoration treatments to no treatments (or natural recovery) over time, and be able to repeat measurements over space and time (USDA 1997). Green (1979) lists ten principles for conducting environmental field studies, all of which are relevant to WRP evaluations. In general, the evaluation design for comparative studies may include:

- a 1 or 2 year (minimum) pre-restoration study at the proposed treatment site(s) to establish baseline conditions;
- a consistent set of variables that are measured with the same intensity and following the same protocols in both pre- and post-restoration evaluation studies;
- a survey protocol for each variable that provides a statistically defensible method for evaluating and minimizing the observer bias inherent in visual estimates or interpretations;
- replicate samples of both the same types and different types of treatments for each combination of sampling time and location; and
- a study design that meets the assumptions for standard statistical analysis, maximizes the power of the statistical test, and results in estimates with known bounds of error.

Common evaluation studies are designed for a single site, and for paired or multiple pairs of treated and control sites. Paired and upstream-downstream comparisons represent two of the simplest forms of a randomized block design (MacDonald et al. 1991). Other possible designs include Before-After/Control-Impact studies or extensive post treatment studies, both of which are reviewed by Mellina and Hinch (1995). These types of study designs are necessary when the effects of management activities need to be separated from changes due to natural variability. An example of the framework for an intensive evaluation project is provided in Appendix I.

Some guiding principles for variable selection as described by MacDonald et al. (1991) are:

- The selection of evaluation variables will differ from watershed to watershed as objectives and site characteristics vary;
- Select variables that are the best indicators of change and measure them in the appropriate areas that are responsive to change;
- Select variables that provide the best evidence/inference that objectives are being met and are least influenced by extraneous events (i.e., natural variability);
- Variables should be independent of timing of inspection and as quantitative as possible;
- Variables should be easily observed, measured and qualified and/or quantified; and

- Variables should be highly sensitive (responsive) to the restoration activity, and have low spatial and temporal variability.

3.4.2.2 Analysis and Presentation of Data

In intensive evaluations, the data are quantitative and usually collected over several years. Consequently, the data for each variable can be analyzed over time and space for each treatment, and comparisons can be made between data sets (Figure 7). Also, comparisons can be made to an established standard (biostandard) to provide a measure of performance or effectiveness. For example, the number of smolts emigrating from a constructed off-channel site can be compared to a published biostandard (number/ha) to provide a relative level of effectiveness.

3.4.2.3 Outputs of Intensive Evaluations

The outputs of intensive evaluations can include the products from routine evaluations, and also:

- recommendations of the experts who worked on the project;
- a determination of the inter-relationships, benefits and complications from the implementation of multiple treatments on roads, landslides, gullies, landings, stream channels and riparian areas;
- scientifically defensible indication of watershed recovery;
- a detailed information basis to specify the 'measure of restoration completeness' for the watershed;
- a determination of better restoration treatments or combinations of treatments; their design, siting and installation; and
- a greater level of confidence in conclusions concerning watershed processes and inter-relationships, allowing for inferences on restoration that can be applied to other watersheds with similar land use impacts.

Intensive evaluation project results should be presented in:

- an Annual Report Summary on WRP Evaluation and/or Key Evaluation Reports that could be appended to a WRP publication, such as *Watershed Restoration Bulletin*, and included on FRBC and/or Provincial Ministries' Web Sites; and
- published reports or primary journal articles of case study findings with management recommendations.

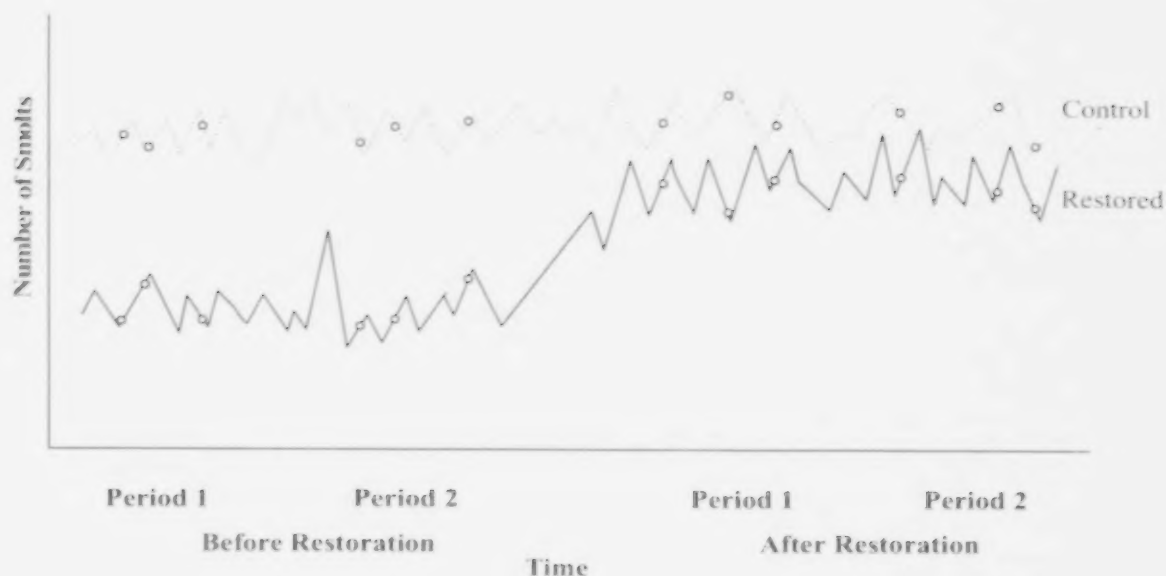


Figure 7. An example of the results for a Before-After-Control-Impact design. The plot shows the change in the number of smolts from multiple randomly chosen sampling occasions in two periods (dots at before and after restoration) in the control (dashed line) or treated sites (solid line). The two temporal scales (sampling periods vs sampling occasions) allows the detection of change in mean and in a change in variability after restoration (modified after Sit and Taylor 1998).

3.4.3 Operational Techniques Refinement

3.4.3.1 Study Design

In operational techniques refinement, highly specific questions are addressed that relate to treatments, application techniques, equipment or materials. For example:

- Is a particular vegetation treatment, hydroseeding, more effective in reducing erosion on deactivated roads than dryseeding?
- Is a Spyder™ excavator more or less cost effective than a conventional excavator in installing in-stream habitat treatments?

Decisions on these questions are usually required as quickly as possible, so these projects are of short duration and often one time only. Generally, pre-restoration data are not mandatory because the evaluator is doing operational tests concurrent with the evaluation. Variables are usually quantitative and can be either physical or biological in nature. An example of the framework for an operational techniques refinement project is provided in Appendix I.

3.4.3.2 Analysis and Output of Data

The statistical analysis required is usually quite basic, but can be more complex depending on the evaluation objectives. Presentation of the data can include:

- graphical displays of performance of various treatments over time, or versus cost of application; and
- amount of measurable work done effectively by particular machines versus cost of operation.

The outputs of operational techniques refinement generally provide decisions on whether or not a new technique, machine, or materials have an appropriate application in watershed restoration, are cost-effective, and provide technical efficiency. For example, results will indicate:

- whether a dragline is better for hill slope pullback than a hydraulic excavator; or
- if erosion blankets are better than hydroseeding for reducing erosion on exposed soils.

Implementing and documenting this evaluation will result in significant cost savings for projects and the Program as the most efficient and cost-effective treatment, material or machine will be applied for each particular site condition.

3.5 Decision Analysis for Selecting an Evaluation Level

After 'determining the general evaluation objectives' for the project and 'identifying program constraints', the level of effectiveness evaluation must be selected (Figure 3). Selection of the most appropriate level of effectiveness evaluation for a project will depend on several parameters, such as:

- Will all of the treatments be sampled or a subset of treatments?
- Are the variables only qualitative or a mix of qualitative and quantitative?
- Does the project require a specific (tailored) study design?
- Will the project be undertaken over several years or within one year?

Progressing through a decision analysis using these parameters will determine if the project is either a routine, intensive or operational techniques refinement form of evaluation. This analysis is independent of whether one or several watersheds are being considered for an evaluation program. Decisions become more focused by referring to specific parameter characteristics for each level of effectiveness evaluations (Figure 1 and Table 1). The systematic selection of the level of effectiveness evaluations is an important and critical step because:

- the requisites and bounds for parameters that are fundamental to a particular level of effectiveness evaluation are made explicit; and
- the most expedient and cost-effective level of effectiveness evaluation is selected.

Four main criteria or 'triggers' can be utilized to elevate projects from routine to intensive evaluations:

- there is an unusually high degree of risk or uncertainty associated with the complexity of treatments in a particular watershed;
- results from increased expenditures to more intensely evaluate those high risk projects will yield significant benefits to subsequent projects (e.g., potential for highest pay-off in terms of contribution to best management practices, widest applicability of findings);
- a greater understanding of functional relationships between physical and biological components and processes is provided; and
- other considerations including easy access, potential for use as demonstration and/or training sites.

4.0 KEY COMPONENTS OF EFFECTIVENESS EVALUATIONS STRATEGY

4.1 Routine Evaluations

Routine evaluations have been undertaken on some completed instream, off-channel and hill slope restoration projects. The evaluations have been funded through Ministry base budgets and Multi-Year Agreements (MYA). Routine evaluations should be a standard part of all future restoration projects, and considered as a 'best practice' when implementing restoration works. All newly completed works should be routinely evaluated for a minimum of one year. Funding should be incorporated into the assessment and implementation stage costs, and included in annual project funding.

Some screening should be done of completed projects where no evaluation has occurred to reveal high risk projects or projects with significant opportunities to, for example, refine innovative restoration treatments. These higher risk or innovative projects should then be routinely evaluated for at least a year with an option to continue evaluations at an intensive level.

Standardized survey protocol and ranking schemes for some evaluation variables that pertain to fish habitat and hill slopes have been established, but additional protocols and ranking schemes should be developed. Standardized survey protocol and ranking schemes for variables that relate to riparian projects are particularly needed.

4.2 Project Selection for Intensive Evaluations and Operational Techniques Refinement

Implementation of a province-wide effectiveness evaluation program for WRP should address three states of project restoration/effectiveness evaluations. These are:

Category 1 - current or completed projects which are presently being evaluated for effectiveness;

Category 2 - completed projects on which effectiveness evaluation have not been conducted; and

Category 3 - current projects of which major work has not yet been completed.

Category 1 projects are rare and evaluations associated with these projects have commonly been at the intensive level requiring significant funding. Regional review of these projects, by specialists, is recommended to determine what benefits have resulted, or are likely to result, from continued funding and what level of future funding is required. Continued funding must be weighed against proposals for new studies of either the intensive evaluation or operational techniques refinement levels.

Category 2 projects have been completed in high priority watersheds and at high risk sites. Potentially, they have much to offer in terms of refining treatment design and assessing cost effectiveness. Routine evaluation of higher risk or innovative projects

should be undertaken to screen for potential intensive evaluations. Potential intensive evaluation studies that arise from the results of these routine evaluations should be selected from proposals that are submitted to regional offices, where a committee of regional agency specialists will review and rank proposals.

Category 3 projects should incorporate considerations for intensive evaluations into IWRPs or into inspections via amendments to Standards Agreements. In this way, one or more years of pre-restoration data can be collected enabling more definitive inferences to be drawn from subsequent effectiveness evaluations. As well, the access management strategy can incorporate access needs for future effectiveness evaluations.

Highest priority for funding of WRP effectiveness evaluations should go to *Category 1* projects that are regionally reviewed and approved, especially those with long term design and pre-treatment data. *Category 2* projects that were innovative or done on high risk sites and in high priority watersheds should be given intermediate priority at this time. It is expected that routine evaluations will identify many of these projects for continued evaluation past year 1; however, costs should gradually decrease over the next five years. *Category 3* projects should have a routine evaluation for at least the first year after completion of works. If *Category 3* projects were directly funded from an evaluation budget rather than from project funds, then they would be assigned the lowest priority at this time. Proposals for intensive evaluation studies on *Category 3* projects should be encouraged as an appropriate study design that includes pre-restoration data can be implemented.

The frequency and duration of evaluations for any project will be somewhat dependent on initial results. Evaluation programs will need to be conducted in an adaptive manner to enable provision of information feedback. Accordingly, a certain amount of flexibility in planning will be key.

4.3 Budgeting Effectiveness Evaluations

We suggest that the overall budget to implement the proposed strategy for WRP effectiveness evaluations be approximately 6% of the annual WRP budget. A suggested funding scenario for the various effectiveness evaluation levels, as a percentage of the annual WRP budget, is:

ROUTINE:	(4%)
INTENSIVE:	(1%)
OPERATIONAL TECHNIQUES REFINEMENT:	(1%)
TOTAL:	6% of annual WRP budget

Initially, a greater proportion of the effectiveness evaluation budget should be spent on existing successful and appropriate evaluation projects, and routine evaluations of

completed high priority/risk projects. This could result in more funds being spent in the first few years, but this has the potential of achieving the greatest benefits to treatment design, siting and installation in the short term, and result in major cost savings over the life of WRP. Over time, these funds would be concentrated into a few long term routine and intensive studies.

Budgets for routine evaluation of Category 3 projects should be included in the Standards Agreement and the Project's annual budget. A mechanism must be developed to ensure that some funds are ear-marked for evaluating a minimum of three times (i.e., three different years as per evaluation protocol) after project completion. The minimum cost for implementing routine evaluations once at a qualitative level throughout a watershed is estimated at 3% of project funds. Funding levels will be commensurate with degree of risk and subject to review by Regional specialists.

4.4 Information Feedback Reporting

Information feedback reporting is a component of the adaptive management cycle, and is a process of converting evaluation results into information and knowledge. It is a value-added process that provides managers with what they need to make sound decisions. It answers questions such as: "Do our evaluation results indicate that we are getting closer to a restored watershed? Do we need to change our objectives? Do our evaluations, treatment designs, or treatment implementation process need fine tuning or change or are they all right?" (USDA 1996).

Even though interpretation of the results occurs after the data is collected and analyzed, the process should have been determined at the outset when objectives were being set. Interpretation of evaluation data should be conducted on a scheduled time frame and should incorporate an early warning system for change. It should objectively measure success or failure, quality control and quality assurance.

In the adaptive management cycle, interpretation and evaluation of results provides feedback to all phases of the cycle (Figure 1). Also, departures from expected results are not treated as failures, but rather as new information. Feedback of this information leads to changes in the management of the Watershed Restoration Program. The management changes could pertain to objectives or restoration strategies. It could also lead to changes in treatment designs and in the process of selecting key watersheds for restoration and prioritizing works within the watershed.

The interpretation of results determines whether or not you are achieving the objective(s). Evaluation results may clearly address the questions raised and meet the stated objectives. However, if the results are inconclusive either the evaluation protocol needs to be modified to provide more precise results, or the management or evaluation objectives need to be modified. Other possibilities are that the measures (indicators) did not address

the problem or that the evaluation assumptions may not have been valid. Evaluation of these possibilities is key to the information feedback component of the adaptive management cycle.

4.5 Reporting/Data Management

Efficient collection, compilation and dissemination of data and results are critical to any effectiveness evaluation program. The information must be conveyed to restoration practitioners, program managers and the public in a timely manner that is easily accessed so that informed decisions can be made on future restoration work. This information will have adaptive management benefits to WRP by:

- ensuring treatment designs and their applications are effective; and
- ensuring funds are spent on the most cost-effective treatments.

Program and quality control standards need to be developed to ensure the highest standard of information is provided. This should include standards on program administration, data collection, and reporting. The standards would ensure:

- quality control for data collection and analysis, and database management;
- that crews have training in the survey protocol for each variable; and
- that the data in effectiveness evaluation reports have been interpreted by specialists.

Collection and compilation of data and results should be handled at the district and regional levels through a new or existing FRBC-funded position. A minimum standard should be established to ensure that routine evaluation data are collected for all watershed components using a standardized protocol (i.e., RIC standards, WRP Technical Circular reports, including any future WRP Technical Circular on Evaluation Procedures, FPC guidelines and field procedures). The data and information should be stored in a centralized database and available to users through a government web site. Also, at a minimum, all intensive and operational techniques refinement projects will be published in Watershed Restoration Management Reports.

Data management and dissemination should be coordinated at the provincial level by an inter-ministry committee such as the Technical Review and Evaluation Working Group (TREWG). Timely dissemination of information could be addressed in a number of ways utilizing both existing and new mechanisms. Existing mechanisms include presentations at annual Watershed Restoration Conferences (Coastal and Interior), publication through the *Watershed Restoration Bulletin* and FERIC's Compendium of Watershed Restoration Activities, annual summaries through the Watershed Restoration Publication Series, and province-wide training initiatives through the BC Forestry Continuing Studies Network. New initiatives include the establishment of an internet web site to provide a venue for communicating evaluation results as they become available, and development of short courses to be held in conjunction with Watershed Restoration Conferences to provide training opportunities for a focused audience.

4.6 Training

Before any routine effectiveness evaluation programs are implemented, training courses will be required for data collectors to ensure that established sampling protocols are followed in a consistent manner. An added benefit of training sessions is the opportunity for feedback, both on the effectiveness evaluation program and the methods of data collection.

Intensive and Operational Techniques Refinement Evaluation Protocols will typically be specific to the evaluation objectives of these studies. Regional specialists should be involved in overseeing these projects to ensure that study designs and sampling protocols for similar studies are consistent between regions. They should also oversee any specialized training that may be required for specific data collection.

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GLOSSARY

Adaptive Management: is a formal process for continually improving (resource) management policies and practices by learning from the outcomes of operational programs. Its most effective form, *active adaptive management*, is characterized by management programs that are designed to experimentally compare selected policies or practices by testing alternative hypotheses about the system being managed. From Glossary of Forestry Terms: adaptive management rigorously combines management, research, monitoring, and means of changing practices so that credible information is gained and management activities are modified by experience.

Bio-Standards: are estimates of abundance or output that are used to predict responses, in terms of increases in fish numbers or biomass, due to specific watershed restoration activities. Typically measured in terms of number or biomass of a species per unit area or kilometer of stream.

Component Level Objective: restoration objectives for watershed components, including hill slopes, riparian areas, streams and fish habitat. Sub-components could include roads, landslides and gullies for hill slopes; streambank and floodplain for riparian; and off-channel and in-channel for streams.

Cost-effectiveness: the usefulness of specific inputs (costs) to produce specified outputs (benefits). In measuring cost effectiveness, some outputs, including environmental, economic, or social impacts, are assigned in physical terms.

Effectiveness Evaluations: assessments that answers the question of whether or not restoration has been effective in attaining or initiating the process to achieve the desired future condition and in meeting restoration objectives. Effectiveness evaluations are more complex than compliance inspections and requires an understanding of the physical, biological and sometimes the social factors that influence ecosystems. The word monitoring may also be used by other agencies, for example the U.S. Forest Service, to refer to evaluations.

Inspections: are conducted during the course of watershed restoration activities to ensure that the work is completed as prescribed or to the standards defined in the contract. The main purpose is to ensure that errors and omissions are corrected prior to payment. Inspections are typically required for all projects with field inspections, and are generally carried out both during and at the completion of restoration works. Inspections may also be referred to as implementation monitoring or compliance monitoring.

Intensive Evaluations: a relatively detailed evaluation involving specialized study design with comprehensive data collection and analysis; generally quantitative measurements, but can include qualitative information. In comparison to routine evaluations, intensive evaluations are more focused and provide statistically defensible

results. Focus can range from evaluation of specific treatments for single restoration objectives to integrated restoration treatments for multiple restoration objectives throughout entire watersheds.

Evaluation Objective: an objective that identifies the reason(s) for conducting effectiveness evaluations.

Evaluation Question: a succinct statement that asks if the restoration objective(s) has been achieved by the treatment(s).

Non-Parametric Tests: do not involve inferences about parameters from the original distribution of measurements. This test is used when normality of the sampled population cannot be assumed or when one or more assumptions underlying a corresponding parametric statistical test have been violated. The tests have been developed for ordinal data (i.e., rank), but are appropriate for interval or ratio level data.

Operational Techniques Refinement: a special category of effectiveness evaluations that requires control and manipulation of restoration treatments in order to answer the questions: did a new treatment work, how well did it work relative to other treatments, and at what cost did it work.

Parametric Tests: involve inferences about parameters from the original distribution of measurements. The tests commonly assume that the population the samples are taken from have a normal distribution. Also, if comparisons are being made between two or more populations, then the test assumes the populations have a common variance.

Program Effectiveness Monitoring: evaluates the overall program (e.g., WRP) with respect to administering, funding, and delivering the individual projects which are carried out under the program.

Qualitative Data: the assignment of a value, such as good or bad, to a variable that would normally lack a means of quantification by standard measurement methods (length, width, volume).

Quantitative Data: the measurement of a value or quantity using standard measurement methods such as volume, duration, length or weight.

Response Indicators: a variable that acts as an indirect indicator of treatment effectiveness.

Response Variable: a variable measured to assess the outcome of an experiment.

Routine Evaluations: a relatively low intensity evaluation, based on answering the question 'Is the treatment present, structurally stable, in need of remedial work and functioning as intended?'; it doesn't require a specialized study design; can include qualitative or quantitative measurements.

Stratification: grouping of sample or survey units into homogeneous groups according to some identifiable characteristic(s). Each stratum is then sampled.

Technical Efficiency: the degree to which a machine or process used in restoration employs technically valid knowledge in an efficient manner to facilitate the production of outputs.

Validation Evaluations: refers to testing of hypotheses that pertain to our level of understanding of how or why a system responds to a disturbance or treatment. The purpose of validation evaluation is to verify the basic assumptions upon which the restoration works are based. Validation evaluation is primarily a research tool with which to examine the basic scientific understanding of how ecosystems work.

Variable: an evaluation parameter that changes measurably in character or number in response to environmental conditions, either through restoration treatments or natural events.

Watershed Level Objective: an objective that describes a desired future condition for the watershed, typically achieved by attaining component level restoration objectives.

APPENDIX 1. Typical Examples of Effectiveness Evaluation Plans (adapted after Kershner 1997).

Routine Evaluation Example

Watershed Level Objectives

- Improve rearing habitat for coho and rainbow trout.
- Reduce the generation of sediments caused by mass-wasting

Component Level Objectives

- Streams
- 1) Balance riffle and pool habitats to obtain a 1 to 1 ratio by stream area
 - 2) Increase cover in existing pools
 - 3) Increase access to existing off-channel habitats

- Riparian Areas
- 1) Establish optimum conifer density to provide an adequate size and number of LWD for future instream habitat
 - 2) Accelerate conifer growth rate in riparian reserve zone

- Hill Slopes
- 1) Reduce the intensity of erosive hydraulic action on exposed mineral soils
 - 2) Restore hill slope drainage networks
 - 3) Reduce the potential of landslides originating from roads

Site-level Objectives

- Streams
- 1) Increase scour in existing pools
 - 2) Increase hydraulic roughness at existing riffles

- Riparian Areas
- 1) Reduce growth competition to conifers from deciduous species

- Hill Slopes
- 1) Stabilize landslide and gully headscarps and sidewalls
 - 2) Improve water conveyance at existing road crossings

Activities

- Streams
- 1) Install regularly spaced rock riffles and boulder clusters in simplified, moderate gradient habitat
 - 2) Place LWD into pool sites in low to moderate gradient stream segments
 - 3) Construct fishway structures at outlets of off-channel, inaccessible beaver ponds

- Riparian Areas
- 1) Plant and/or space conifers
 - 2) Reduce proportion of competing hardwood species
 - 3) Fertilize conifers

- Hill Slopes
- 1) Revegetate landslide tracks by seeding, planting and/or bio-engineering
 - 2) Re-construct undersized or collapsed stream crossings
 - 3) Revegetate denuded gully sidewalls
 - 4) Deactivate roads at risk of initiating a landslide

Effectiveness Evaluation Questions

- Streams
- 1) Has the cover in existing pools and riffles increased?
 - 2) How many of the constructed fishways successfully provide fish access to the off-channel ponds?

- Riparian Areas
- 1) Have the restoration treatments increased the growth rate of conifers?

- Hill Slopes
- 1) Has revegetation of the landslide tracks reduced the area of exposed mineral soils?
 - 2) Has deactivation of roads at risk decreased the number of road related failures?
 - 3) Has reconstruction of road crossings reduced the number of road failures caused by impeded drainage?

Study Design

Evaluation Variables

- number of landslides from deactivated roads and downslope areas;
- percent vegetative cover on rehabilitated landslides, gully sidewalls and deactivated roads using ordinal rating categories;
- evaluation of present stability of rehabilitated landslides and gullies using rating categories;
- functional condition of water management structures (cross-ditches, fords, etc) using rating categories;
- annual growth of conifers;
- residual pool depth;
- % cover;
- pool-riffle ratio;

- presence/absence of coho and trout;
- instream structure stability and condition using rating categories.

Sampling

Streams: walk through review of all installations after first year to determine habitat complexity and functional stability and condition; measure residual pool depths; presence/absence of coho and trout using Gee traps or through visual observation; sampling every five years thereafter or after a major run-off event.

Riparian Areas: annual inspection of sample plots or transects to determine annual growth of conifers; once stand reaches free to grow, inspection every five years.

Hill Slopes: annual aerial review of all works to determine if post-deactivation road-related landslides have occurred; if surface flow is still contained in intended channels; aerial and/or ground review of landslides and gullies to determine stability of headscarp/sidewalls and % vegetative cover; sampling may be terminated when residual risk is deemed acceptable.

Intensive Evaluation Example

Watershed Level Objectives

- Reduce sediment delivery from hill slopes to streams
- Improve in-stream rearing habitat for salmonids

Component Level Objectives

- Streams
- 1) Increase residual pool depth in primary pools
 - 2) Increase cover for juvenile coho and rainbow trout

- Riparian Areas
- 1) Increase potential for stream bank stability
 - 2) Preferentially accelerate conifer growth in riparian reserve zone

- Hill Slopes
- 1) Reduce soil forces that potentially cause angles of internal friction to be exceeded
 - 2) Increase the factor of safety on landslide tracks
 - 3) Reduce the potential for debris flows in gullies

Site-level Objectives

- Streams
- 1) Increase scour in existing pools

- Riparian Areas
- 1) Increase soil cohesion on stream banks
 - 2) Reduce growth competition to conifers from deciduous species

- Hill Slopes
- 2) Increase soil shear strength
 - 3) Decrease amount of unstable material in gullies

Activities (Prescriptions)

- Streams
- 1/2) Install LWD structures in pools at chainages 500, 550, 600 and 655 m

- Riparian Areas
- 1) Plant conifers on right bank between chainages 5 and 55 m
 - 2) Brush alders on left bank between chainage 0 and 290 m

- Hill Slopes
- 1) Permanently deactivate unstable roads between 5 and 8 km along spur W104
 - 2) Seed and plant trees on landslides identified as A1, A4 and A7
 - 3) Clean gullies of fill at road crossings

Effectiveness Evaluation Questions

- Streams
- 1) Have LWD structures increased residual pool depth?
 - 2) Has the cover in pools used by coho and rainbow trout increased?
- Riparian Areas
- 1) Is the zone of influence by conifer roots maintaining streambank soil intact?
 - 2) Has brushing alder permitted conifer growth to outpace competing brush species?
- Hill Slopes
- 1) Has road deactivation decreased the number and size of road-related failures?
 - 2) What area of rehabilitated landslide has continued erosion on exposed mineral soils?
 - 3) Has the size and frequency of debris flows decreased?

Study Design:

Evaluation Variables (not an exhaustive list)

- number and area of recent landslides and debris flows at rehabilitated and non-rehabilitated sites;
- number and area of road related landslides (deactivated vs non-deactivated roads);
- % vegetative cover on landslides;
- conifer seedling survival;
- annual growth of conifers;
- length of eroding/sloughing streambank;
- LWD pieces per bankfull channel width;
- residual pool depth;
- % LWD cover;
- pool frequency;
- number of juvenile coho and rainbow trout per unit area;
- size at age for juvenile coho and rainbow trout.

Sampling

For all components, the study design recommends sampling at control and treatment sites, with replicates for both controls and treatments.

Streams: annual field evaluation of all variables in both the control and treatment sections until recovery is established. Evaluation frequency may be decreased to every three years or longer once structures have stabilized.

Hill Slopes: sample selected road sections twice a year after extreme events in fall and spring; detailed ground sampling with fixed photo sites.

Riparian Areas: annual inspection of sample plots to determine conifer seedling survival; annual growth of conifers.

Operational Techniques Refinement Examples

Watershed Level Objectives

- Optimize the cost effectiveness and technical efficiency of restoration treatments.

Component Level Objectives

Streams 1) Increase cover in existing pools for juvenile coho.

Riparian Areas 1) Accelerate conifer growth in riparian reserve zone.

Hill Slopes 1) Reduce road-related mass-wasting from unstable fills.

Effectiveness Evaluation Questions

Streams 1) Was the Spyder™ hoe more cost-effective and less damaging environmentally than a conventional hydraulic excavator at yarding and installing LWD in pools?

Riparian Areas 1) Did partial or complete red alder overstory removal provide the better conifer growth?

Hill Slopes 1) Was using a dragline for fill slope pullback rather than a hydraulic excavator more effective at reducing fill slope failures?

Study Design

Evaluation Variables

- number of road fill slope failures following deactivation;
- conifer growth rate;
- cost-effectiveness;
- assessment of extent (i.e., area/length) and severity (i.e., high, moderate, low) of damage to stream habitat and riparian zone;
- conformity with treatment design.

Sampling

Largely dependent on evaluation objectives; sampling may be one time only.